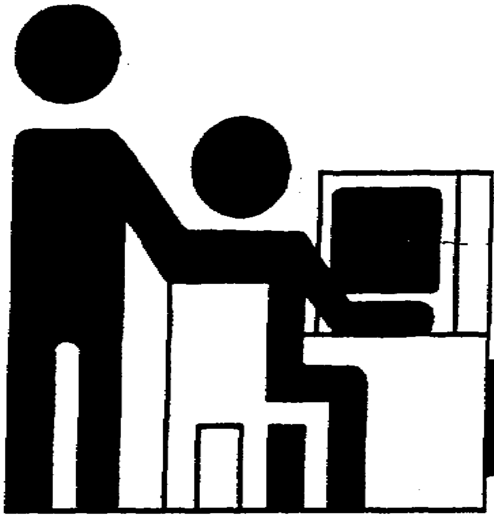
SUBCOURSE EDITION

MM 0322 9

AM RADIO RECEIVERS

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT

ARMY CORRESPONDENCE COURSE PROGRAM



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Use the Ordnance Training Division website,
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SIGNAL SUBCOURSE 322
AM RADIO RECEIVERS

PLEASE NOTE

Proponency for this subcourse has changed

from Signal (SS) to Missile & Munitions (MM).

***** IMPORTANT NOTICE *****

THE PASSING SCORE FOR ALL ACCP MATERIAL IS NOW 70%.

PLEASE DISREGARD ALL REFERENCES TO THE 75% REQUIREMENT.

SIGNAL SUBCOURSE 322-9, AM RADIO RECEIVERS

INTRODUCTION

Everywhere you look today you see adults, teenagers, and subteens listening to radios. At the beach, in the family car, at home, in restaurants, or just about anywhere else, man has at his fingertips music, comedy, drama, sports, weather, and news. All he has to do is turn on his radio. The housewife can listen to her favorite soap opera while she is doing the ironing. The Ham comes home from work and turns on his "rig" to try to raise another Ham in Cairo, Rome, or maybe Calcutta.

Consider the modern fireman, policeman, cab driver, member of the military, or any number of other businesses or professions. Radio communication has become a part of his life.

Today's sophisticated radios have evolved from the primitive equipment used by Marconi. Whether a radio receiver is designed for communication or for entertainment, there are many similarities. Many of the circuits used in broadcast receivers are identical with those in communication receivers.

To have a thorough knowledge of radio communications, you must have some background in AM receiver fundamentals. This subcourse is designed to give you that background.

This subcourse consists of five lessons and an examination as follows:

Lesson 1. Radio Receiver Characteristics

Lesson 2. Signal Input Circuits

Lesson 3. IF Amplifier and Detector Circuits

Lesson 4. Audio Circuits and Reproducers

Lesson 5. Radio Receiver Operation and Circuit Analysis

Examination

Credit Hours: 10

The only time limitation placed on you is that you must complete this subcourse within 1 year from the date of initial enrollment.

Texts and materials furnished:

Subcourse Booklet

TM 11-665, C-W and A-M Radio Transmitters and Receivers, September 1952 (EXTRACTED)

Reviewed and reprinted with minor revisions, March, 1979.

EDITION 9
10 CREDIT HOURS
REVIEWED 1988

LESSON 1

RADIO RECEIVER CHARACTERISTICS

SCOPE ....Reception of radio waves; block diagram of AM radio receiver; beat frequencies; mixers; selectivity; sensitivity; fidelity; signal-to-noise ratio.

CREDIT HOURS 1

TEXT ASSIGNMENT ....TM 11-665, para 102, 106, 122-126

MATERIALS REQUIRED ....None

SUGGESTIONS ....Disregard references to trf receivers in the text. This subcourse deals only with superheterodyne receivers.

LESSON OBJECTIVES

When you have completed this lesson, you will be able to:

1. Describe the characteristics of a mixer.

2. Describe the effects of selectivity, sensitivity, and signal-to-noise ratio on radio reception.

3. Explain the principles of heterodyne action.

4. Analyze each stage of a radio receiver, using the block diagram.

DNI CORRECTIONS TO TM 11-665

Page 167, para 102b, line 8, delete "I-C (inductance-capacitance)" and substitute L-C (inductance-capacitance) circuits.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. By changing the frequency of the incoming signal to a frequency of fixed value, the radio receiver provides maximum

a. stability, selectivity, and sensitivity.

b. stability, sensitivity, and fidelity.

c. fidelity, selectivity, and stability.

d. sensitivity, fidelity, and selectivity.

2. Assume that the mixer stage of a radio receiver is fed an input frequency of 7,100 kHz and a local oscillator frequency of 7,130 kHz. What is the beat frequency generated by the mixer?

a. 30 Hz

b. 300 Hz

c. 3 kHz

d. 30 kHz

3. The intermediate frequency selected for a radio receiver is usually well above the highest AF component in the desired signal because the

a. oscillator is more stable at higher frequencies.

b. heterodyne action is more efficient at higher frequencies.

c. possibility of distorting the desired signal is reduced.

d. higher frequencies are more easily amplified.

4. Assume that two alternating currents differing in frequency are applied to a linear device such as a resistor. The voltages appearing across the resistor will contain what frequencies?

a. Frequencies twice the value of the applied frequencies

b. The original frequencies of the applied alternating currents

c. A frequency equal to the sum of the original applied frequencies

d. A frequency equal to the difference of the two applied frequencies

5. The selectivity of a radio receiver is improved by

a. increasing the percentage of frequency separation without changing the numerical frequency separation.

b. amplification of the signal at high fixed frequencies.

c. the use of resistance-capacitance coupling systems.

d. the use of diode detectors.

6. The IF stage in a radio receiver performs some important functions. One purpose of this stage is to

   a. amplify the fixed-tuned signal before demodulation.

   b. remove audio modulation and filter out the RF carrier.

   c. combine the input signal with the output of the local oscillator.

   d. convert electrical audio-frequency variations into corresponding sound waves.

7. Tuned LC circuits are commonly used in radio receivers to provide signal

   a. amplification

   c. detection.

   b. modulation.

   d. selection.

8. What characteristic of a radio receiver gives the receiver the ability to reject all frequencies except the desired frequency?

   a. Fidelity

   c. Sensitivity

   b. Stability

   d. Selectivity

9. Assume that the carrier frequency of a transmitter is 970 kHz and the highest modulating frequency is 5 kHz. What band of frequencies must be passed by the tuned circuits in the RF amplifiers in the receiver?

   a. 970 to 975 kHz

   c. 965 to 975 kHz

   b. 960 to 980 kHz

   d. 967.5 to 972.5 kHz

10. The receiver characteristic which is measured by the minimum signal input voltage that will provide a standard signal output power is the

   a. fidelity.

   c. sensitivity.

   b. stability.

   d. selectivity.

11. Static noise in a radio receiver is commonly caused by

   a. electric motors.

   b. diathermy machines.

   c. atmospheric disturbances.

   d. spark plugs in auto engines.

12. Most noises introduced into a receiver from an external source have the form of transient disturbances. These disturbances are called

   a. hum.

   c. shot effects.

   b. impulses.

   d. thermal agitation.

13. The signal-to-noise ratio limits the maximum sensitivity of a radio receiver. The signal-to-noise ratio is a number that represents the ratio of the input signal to the

a. external noise created by atmospherics.

b. shot-effect noise created by electron tubes.

c. internal noise caused by thermal agitation of components.

d. total noise that appears with the signal in the useful frequency band.

14. On the front panel of most communication radio receivers are found controls for tuning, output volume, sensitivity, and bandwidth. The control that is most effective in improving the signal-to-noise ratio is the control that adjusts

a. tuning.

b. bandwidth.

c. sensitivity.

d. output volume.

15. Interference between receivers located in the same area becomes a possibility if the local oscillator signals of the receivers are radiated by the antennas. This interference can best be suppressed by

a. using RF amplifier stages.

b. neutralizing the RF amplifier circuits.

c. shielding the oscillator circuits and leads.

d. using an efficient antenna-coupling device to reduce signal loss.

CHECK YOUR ANSWERS WITH LESSON SOLUTIONS ON PAGE 49.

LESSON 2

SIGNAL INPUT CIRCUITS

SCOPE ....Antenna coupling; interstage coupling; RF amplifiers; frequency conversion and tracking; oscillator stability; transistorized RF amplifiers, mixers and local oscillators.

CREDIT HOURS 2

TEXT ASSIGNMENT ....TM 11-665, para 107-112, 127-134, 149;

Attached Memorandum, para 2-1 through 2-4

MATERIALS REQUIRED ....None

SUGGESTIONS ....Read assignment in TM 11-665 before reading the attached memorandum.

LESSON OBJECTIVES

When you have completed this lesson, you will be able to:

1. Identify the various methods of antenna coupling and interstage coupling.

2. State the characteristics of triode and pentode RF amplifiers.

3. Explain the characteristics of mixers and frequency converters.

4. Perform frequency tracking adjustments in a receiver.

5. State the importance of stability in local oscillators.

6. Explain the operation of transistorized RF amplifiers, mixers, and local oscillators.

ATTACHED MEMORANDUM

2-1. TRANSISTORS USED IN AM RADIO RECEIVERS

Transistors used in AM radio receivers can be classified into two groups: low-power and high-power. Junction types are preferred to the point-contact

types because of their lower internal capacitance and their excellent gain at frequencies up to several megahertz. Low-power transistors can be either the PNP or NPN variety, and are usually found in RF and IF amplifiers, oscillators, mixers, detectors, and preamplifiers. High-power transistors are usually of the PNP variety, and are used as either single-ended class A, or as push-pull class AB or class B audio output amplifiers.

2-2. RF AMPLIFIER

A transistorized RF amplifier is shown in figure 2-1. This amplifier uses an NPN transistor in a grounded-emitter circuit in which the emitter is common to both the input and output circuits.

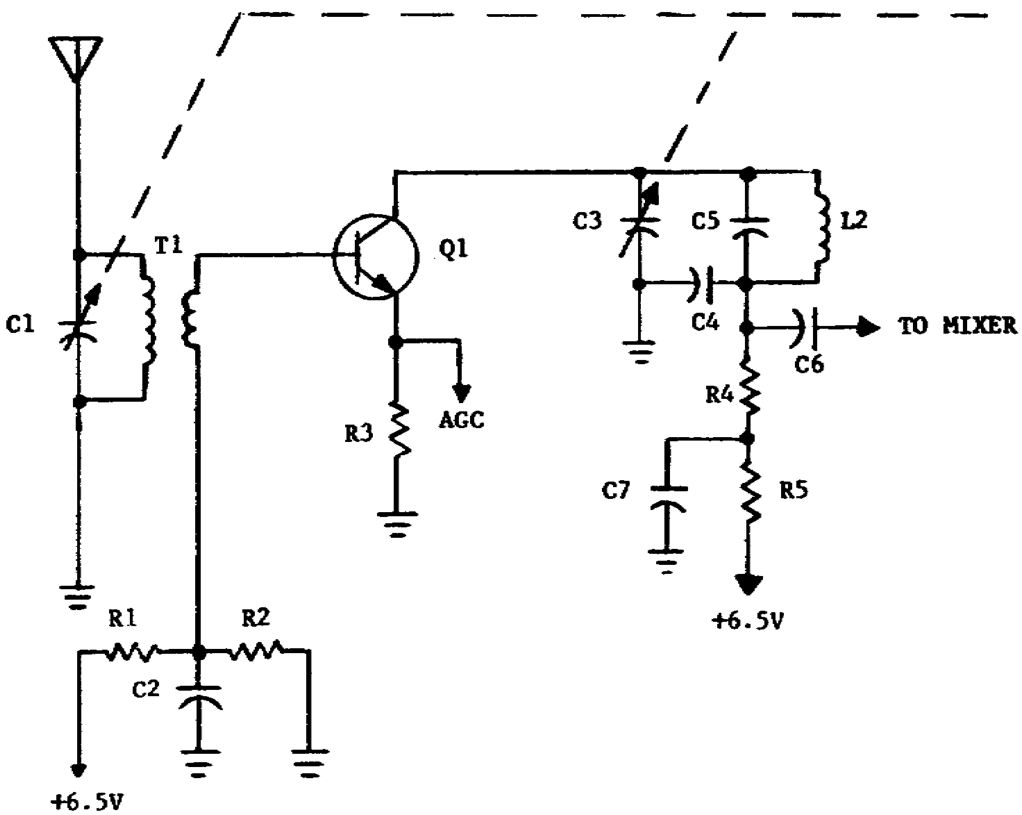

Figure 2-1. RF amplifier.

a. Input Signal Path. The antenna input signal is coupled through transformer T1 to the base of the transistor. The T1 is a voltage stepdown transformer that is used at this point to match the low-impedance emitter-base junction to the high impedance of the antenna input circuit.

b. Biasing. A forward bias voltage of +2.5 volts is developed by the voltage-divider network, consisting of resistors R1 and R2, which is connected in series with the +6.5-volt supply. This positive bias voltage causes electrons to flow from emitter to collector, resulting in collector current through L2, R4, and R5. The collector current and a very small base current return

to the emitter through ground and R3 (the stabilizing resistor). This current causes a voltage drop of 2.1 volts across R3, which reduces the forward bias between base and emitter to the difference between +2.5 and +2.1 volts (base minus emitter voltages), or +0.4 volt. This small voltage is increased by the AGC voltage connected to the emitter when a strong signal is received. Thus, a strong signal causes the AGC voltage to become more positive; this increases the emitter positive voltage, thereby reducing stage gain.

c. Output Signal Path. The +6.5 volts applied to the collector circuit is reduced to +5 volts at the collector because of the voltage drop in the collector series resistors R4 and R5. The collector-current signal variations appear across L2 and the collector resistors. Note that capacitors C1 and C3 are ganged to achieve tracking. Tank circuit L2-C5, tuned by C3, forms a high-impedance output circuit. Resistor R4 and capacitor C6 combine to form a low-impedance circuit to match the impedance of the mixer circuit.

2-3. MIXER

A mixer stage using an NPN transistor is shown in figure 2-2. Like the RF amplifier just described, this mixer uses a grounded emitter common to both input and output (base and collector) circuits.

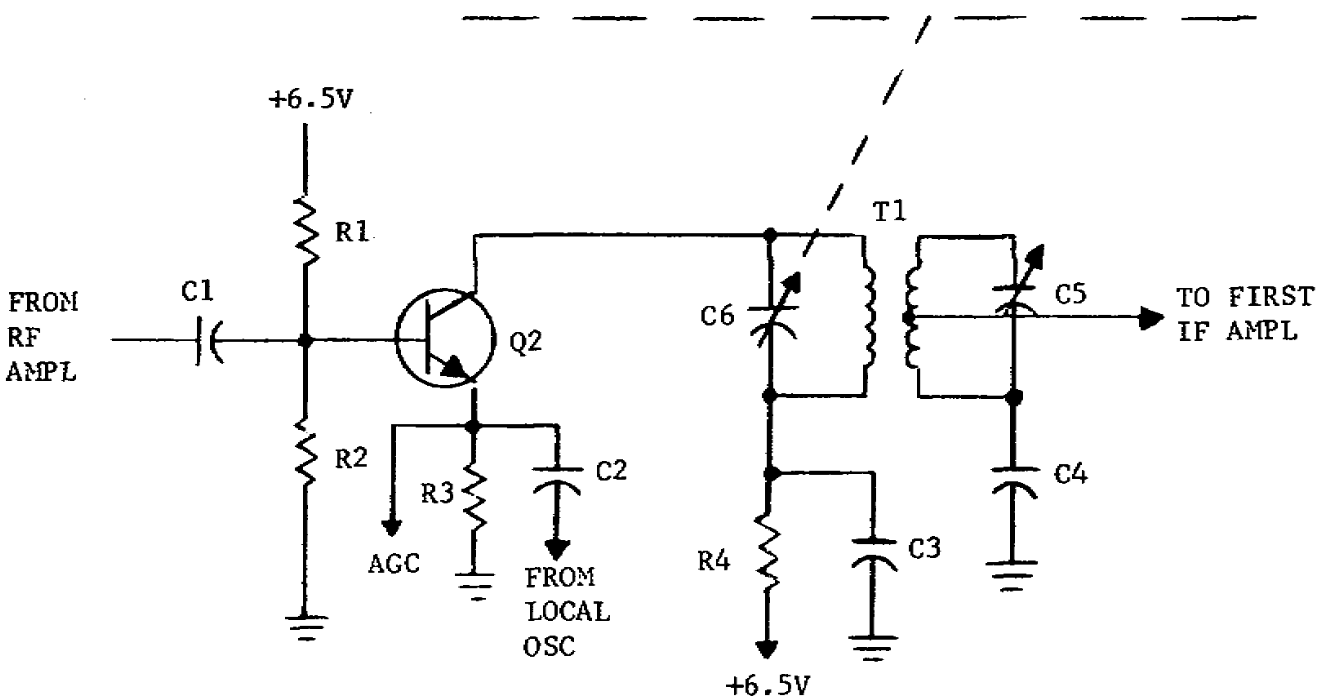

Figure 2-2. Mixer.

a. Input Circuit. The input circuit receives the signal from the RF amplifier through coupling capacitor C1. The signal voltage developed across R2 is impressed across the base-emitter junction. The local oscillator signal that is to be mixed with the input RF signal is coupled into the emitter-base junction by capacitor C2.

b. Transistor Characteristic Curve. Transistors have characteristic curves similar to the curves for electron tubes. In figure 2-3 the characteristic curve (base current vs collector current) shows that at the high and low current portions of the curve (I_B = 0 to 10 and 35 to 50 microamperes) the amount of collector current change is not the same for each microampere of change in base current. The curve is nonlinear in these areas. Between the extremes (IB = 10 to 35 microamperes), the collector current will change approximately the same amount for each microampere of change in base current. This portion of the characteristic curve is linear.

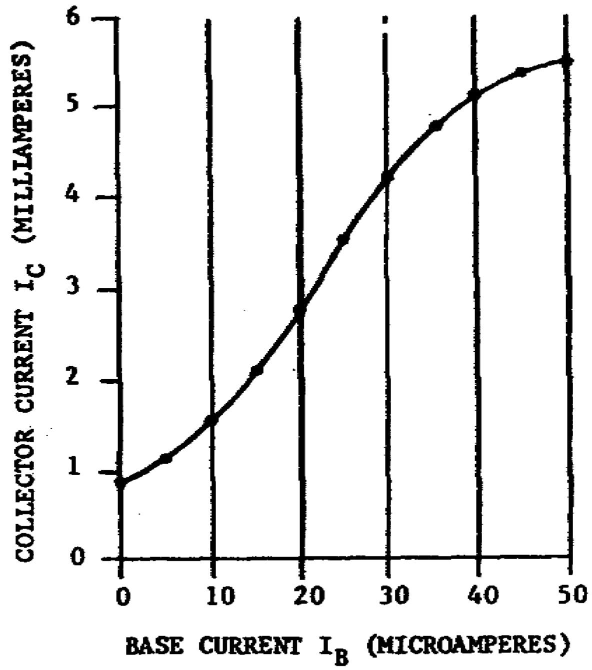

Figure 2-3. Typical transistor characteristic curve.

c. Biasing. In figure 2-2, a voltage-dividing network consisting of R1 and R2 in series with the +6.5-volt supply biases the emitter-base junction to +1.6 volts. The collector current flowing through stabilizing resistor R3 produces +0.85 volt, which opposes the +1.6 volts and makes the total bias voltage +0.75 volt. The transistor is being biased in the low-current region, producing nonlinear characteristics. As the local oscillator voltage swings from one signal peak to another, the emitter voltage will change. The negative swing of the oscillator voltage will oppose the 0.85-volt drop across R3, thus providing less opposition to the +1.6 volts at the base-emitter junction. This increases the forward bias and causes the transistor to conduct more heavily (not to saturation). The positive swing of the oscillator voltage aids the +0.85-volt drop across R3, providing more opposition to the +1.6 volts at the junction. This decreases the forward bias and causes the transistor to conduct less heavily (not to cutoff). As the transistor passes

through the nonlinear portion of the low-current end of the curve, the local oscillator frequency will mix with the incoming RF signal producing four frequencies that will appear in the collector current: the local oscillator frequency, the received signal frequency, the sum of the two, and the difference between the two. As with any other type of receiver, efficient mixing requires that the local oscillator signal voltage be stronger than the incoming signal voltage.

d. Output Circuit. The collector current varies at the rate of both the RF signal and the local oscillator frequencies. Modulation (mixing) occurs as a result of nonlinear operation, and the difference frequency from the mixing action becomes the intermediate frequency. Transformer T1 is tuned to select the intermediate frequency, and all other modulation components (frequencies) are ignored by the tuned circuit. A double-tuned transformer is used so as to obtain a broad intermediate-frequency (IF) response and, at the same time, to realize a resonant rise of voltage in the secondary. A tap on the secondary winding provides a low-impedance output for the next stage. Resistor R4 and capacitor C3 form a filter network to rid the collector current of undesired frequencies.

2-4. LOCAL OSCILLATOR

The oscillator stage, also employing a common-emitter circuit, is shown in figure 2-4.

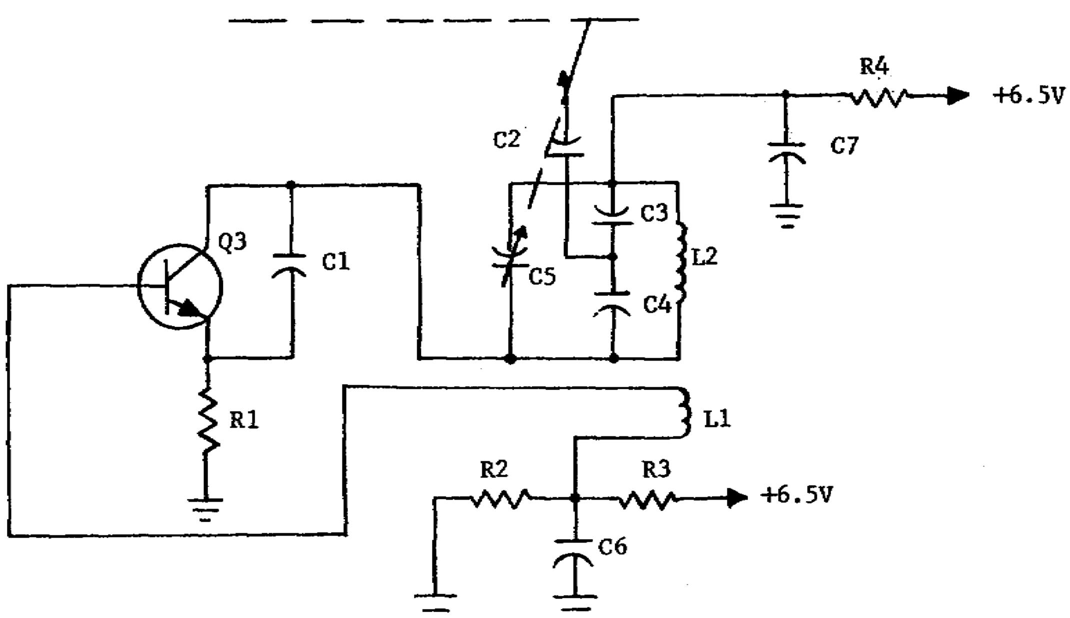

Figure 2-4. Local oscillator.

a. Feedback Circuit. The circuit is connected in a tuned-collector arrangement that uses an untuned base coil L1 to provide the inductive feedback necessary to sustain oscillations. Capacitor C5 tunes coil L2 to the

oscillator frequency, which is above the incoming signal frequency by the amount of the IF. Capacitor C5 is normally ganged with the tuning capacitors of the RF amplifier and the mixer to maintain frequency tracking.

b. Biasing Arrangements. Self-biasing resistor R1 has a degenerative effect on the oscillator, since the voltage drop across it causes the emitter to go positive during the conduction part of the cycle. The result is that excessive collector current and tank circuit loading is prevented, which aids in maintaining oscillator stability. Forward base-emitter biasing is obtained by the R2-R3 voltage divider connected in series with the +6.5 voltage source. AGC is not used, because the oscillator circuit must be self-regulating to maintain a stable output level.

c. Output Voltage. The output voltage is coupled to the mixer from the low-impedance point between voltage-dividing capacitors C3 and C4. The low-impedance tap is necessary to match the input impedance of the mixer base-emitter circuit.

d. Ganged Tuning. In the foregoing circuit diagrams, a ganged capacitor arrangement is used for tuning. Many transistor radio receivers use ganged variable slug tuning rather than ganged capacitor tuning. In slug tuning, the tuning coils are equipped with movable ferrous cores. Sliding ganged cores in and out of the inductors simultaneously varies the impedance of all the tuning coils. Such arrangements require the use of fixed capacitors. The slug tuning method is popular with radio receiver designers because of its low cost and small size.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. Four typical antenna-coupling circuits are shown in figure 159 of TM 11-665. A brief comparison of these circuits shows that the greatest sensitivity and selectivity will be produced by the circuit shown in sketch

a. A.　　c. C.

b. B.　　d. D.

2. Bandswitching is used in communication-type receivers when design difficulties limit the use of some circuit components. Bandswitching is necessary in these receivers because

a. tracking and alignment are simplified.

b. different tuning capacitors are required for each tuning range.

c. the frequency range of one coil and tuning capacitor is limited.

d. interference caused by crowding too many stations on a small portion of the dial is reduced.

3. One result of adding the screen and suppressor grids to the electron tube has been to

a. eliminate the necessity for an AVC circuit.

b. increase the ability of a tube to self-oscillate.

c. make it possible to inject two signals into the same tube.

d. reduce the interelectrode capacitance and increase the gain.

4. What is the one characteristic that is common to all frequency converters?

a. All frequency converter circuits require the use of two tubes.

b. The oscillator voltage and the RF signal must be injected at different electrodes.

c. All frequency converters use the nonlinear portion of the tube characteristic for mixing.

d. Since the gain of a frequency converter is slight, signal-to-noise ratio is not an important consideration.

5. High conversion gain is desirable in a converter stage because the signal voltage applied to this stage is normally low. A high conversion gain can be obtained in the converter stage by

a. maintaining a low value of load impedance.

b. maintaining a high value of conversion transconductance (Gc).

c. isolating the local oscillator from the RF signal circuits.

d. using a converter tube with remote cutoff characteristics.

6. In the frequency conversion circuit shown in figure 174 of TM 11-665, the oscillator signal is coupled to the mixer stage by the grid injection method. When this method of coupling is used, maximum conversion gain is obtained by

a. keeping the oscillator voltage to a value less than the signal voltage.

b. adjusting the bias to a value approximately equal to the signal voltage.

c. limiting the oscillator voltage to a value slightly higher than the fixed bias voltage.

d. keeping the sum of the oscillator voltage and signal voltage slightly less than the mixer bias.

7. Interaction between the local oscillator and the RF signal circuits causes the frequency of the local oscillator to change. This type of change in local oscillator frequency is known as

a. fading.

b. pulling.

c. tracking.

d. conversion.

8. When a pentagrid mixer is used for frequency conversion (as in figure 177, TM 11-665), the RF signal and the signal from a local oscillator are applied to separate grids in the mixer tube. The signal from the oscillator is normally applied to grid number

a. 1.

b. 2.

c. 3.

d. 4.

9. In the triode-hexode converter tube, the electron stream of the mixer section is modulated at the oscillator frequency. The coupling between the oscillator and mixer sections is accomplished by

a. interelectrode capacitance coupling.

b. electron stream coupling.

c. a mixer-injection grid.

d. cathode coupling.

10. In the pentagrid converter shown in figure 181 of TM 11-665, grid 2 has the function of

a. accelerating the electron stream.

b. acting as an electrostatic shield.

c. acting as the plate of the oscillator.

d. isolating the oscillator from the RF signal.

11. To simplify frequency tracking in a receiver, the same size tuning capacitors may be used for both the oscillator and the mixer. Frequency tracking in this case is achieved by adjusting the

a. IF tuning capacitors.

b. mixer tuning capacitor.

c. oscillator tuning capacitor.

d. oscillator trimmer and padder capacitors.

12. A wavetrap like that shown in B of figure 198, TM 11-665, is to be used to eliminate image interference when the receiver is tuned to 15,252 kHz. The IF is 462 kHz and the oscillator is tuned higher than the incoming signals. The frequency to which the wavetrap should be tuned is

a. 14,328 kHz.

b. 14,790 kHz.

c. 15,714 kHz.

d. 16,176 kHz.

13. The RF stage shown in figure 199 of TM 11-665 has both automatic gain control and manual gain control. Both automatic and manual control circuits control the output of the RF stage by

a. varying the bias voltage.

b. varying the cutoff point of the amplifier.

c. counteracting completely the effects of fading.

d. permitting a more favorable image rejection ratio.

14. Double-conversion receivers are often used in very high frequency (VHF) radio systems. The primary purpose of double conversion in VHF receivers is to provide

a. higher gain.

b. better selectivity.

c. reduced image response.

d. higher signal-to-noise ratio.

15. The type of transistor usually used in the AF amplifier stages is classified as a

a. low-power PNP.

b. low-power NPN.

c. high-power PNP.

d. high-power NPN.

16. In figure 2-1 of the attached memorandum, a voltage stepdown transformer is used between the antenna and the transistor of the RF amplifier. The transformer is needed because the

a. strong signals easily overload the RF amplifier.

b. reverse bias is applied to limit output current.

c. bias voltage prevents the RF amplifier from amplifying weak signals.

d. antenna impedance is high compared with the impedance of the RF amplifier.

17. The mixer shown in figure 2-2 of the attached memorandum must operate on the nonlinear portion of its characteristic to achieve efficient mixing action. Efficient mixing action is therefore achieved when the

a. incoming signal voltage exceeds the bias voltage.

b. incoming signal voltage exceeds the local oscillator output voltage.

c. negative peaks from the local oscillator drive the transistor into heavy conduction.

d. positive voltage peaks of the combined RF and local oscillator signals cause heavy conduction to occur.

18. Transformer T1 in figure 2-2 selects only the IF from all the frequencies generated during the mixing process. The IF in the receiver can be simply described as the

a. difference between the RF input and local oscillator signals.

b. difference between the two sidebands of modulation.

c. sum of the local oscillator and input RF signals.

d. sum of the two sidebands of modulation.

19. To sustain oscillations in an oscillator, there must be some regenerative feedback. In the circuit shown in figure 2-4, regenerative feedback is accomplished

a. by L1.

b. by C2 and R1.

c. by C6 and R1.

d. through the power supply.

20. Degeneration in the local oscillator circuit of figure 2-4 aids in maintaining oscillator stability. This degenerative voltage is developed by resistor

a. R1.

b. R2.

c. R3.

d. R4.

CHECK YOUR ANSWERS WITH LESSON SOLUTIONS ON PAGE 50.

LESSON 3

IF AMPLIFIER AND DETECTOR CIRCUITS

SCOPE ....Detection; IF amplifier; IF tuning; typical IF circuit; typical detector; AVC; transistorized IF amplifiers and detectors.

CREDIT HOURS 2

TEXT ASSIGNMENT ....TM 11-665, para 113-114, 135-143; Attached Memorandum, para 3-1 through 3-3

MATERIALS REQUIRED ....None

SUGGESTIONS ....a. Read assignment in TM 11-665 before reading attached memorandum.

....b. TM 11-665 considers automatic volume control (AVC) and automatic gain control (AGC) to be one and the same. The attached memorandum uses the same approach.

LESSON OBJECTIVES

When you have completed this lesson, you will be able to:

1. Explain the operation of the most frequently used detectors.

2. Explain how AVC or AGC circuits prevent extreme variations in volume although the received signal is fluctuating in strength.

3. Explain how IF amplifiers are used to provide good selectivity and gain.

4. Explain the operation of transistorized IF amplifiers and detectors.

ATTACHED MEMORANDUM

3-1. TRANSISTORIZED IF AMPLIFIERS

In AM radio receivers employing electron tubes, the voltage gain of an IF amplifier can be as high as 100. However, because the gain of a transistor IF amplifier stage is only about one-third or one-half that of its tube counterpart, two or three transistor IF stages are used. Figure 3-1 shows the circuit of a transistorized first IF amplifier in an AM receiver.

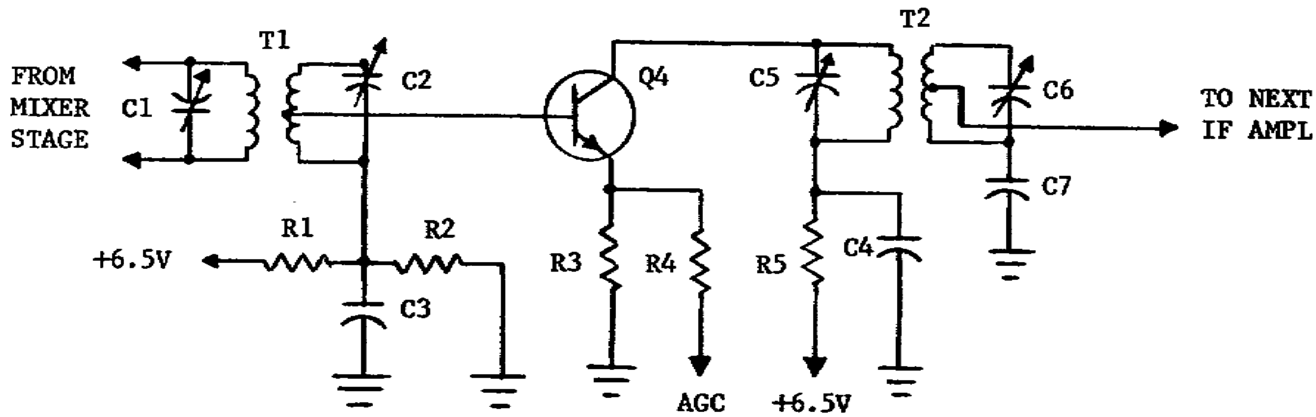

Figure 3-1. IF amplifier.

a. Circuitry. Most IF amplifiers have rather simple circuit configurations. They normally use inductive coupling through input and output transformers. The remainder of the circuit is associated with the amplifying element, in this case, the transistor.

(1) The input transformer, T1, is usually double-tuned and coupled so as to achieve the bandwidth required of the signal being passed. The secondary is tuned to improve selectivity. Tuning capacitors C1 and C2 are individually adjusted. Many IF transformers use fixed capacitors and the inductance is varied by adjustable slugs. The primary winding of transformer T1 is the tuned output circuit of the mixer. The secondary is tapped at a low-impedance point to match the impedance of the transistor input.

(2) The transistor is an NPN type connected in a common-emitter circuit.

(3) The output transformer, T2, is similar in most respects to the input transformer. In communication-type receivers, one of the two windings in the IF transformers is sometimes made movable so that the degree of coupling can be varied. The bandwidth can be adjusted to accommodate narrow-band signals in this manner. A second method of controlling the bandwidth is to insert a band-limiting filter in the string of IF amplifiers. Still another way is to insert into the IF channel a crystal that is cut to pass a narrow portion of the IF band.

b. Biasing. The secondary of T1 is connected to ac ground through C3. A dc ground is not used at this point because it would prevent the needed +0.7 volt from appearing at the base-emitter junction. This voltage is developed by resistance network R1-R2 connected in series with the +6.5-volt dc source. The emitter voltage of +0.5 volt is developed by a collector current of about 0.5 milliampere (ma) flowing through R3. Also applied to the emitter through R4 is the AGC voltage. This voltage reduces the forward bias on strong

signals, and keeps the receiver sensitivity fairly level since it reduces stage gain. The amplifier operates essentially as a class A stage, with the collector output signal appearing across the primary of transformer T2. The ac component of the collector current is induced in the secondary of transformer T2. This output transformer also serves as the input transformer of the following IF amplifier stage.

c. Choice of IF. A commonly used IF in transistor radio sets is 262 kHz, because greater gain and more stability can be obtained when the receiver is designed to operate with a lower IF than the 455 kHz commonly found in electron-tube receivers. However, the lower IF has the disadvantage in that it makes the receiver more susceptible to image frequency pickup.

3-2. TRANSISTOR DETECTOR CIRCUIT

(fig. 3-2)

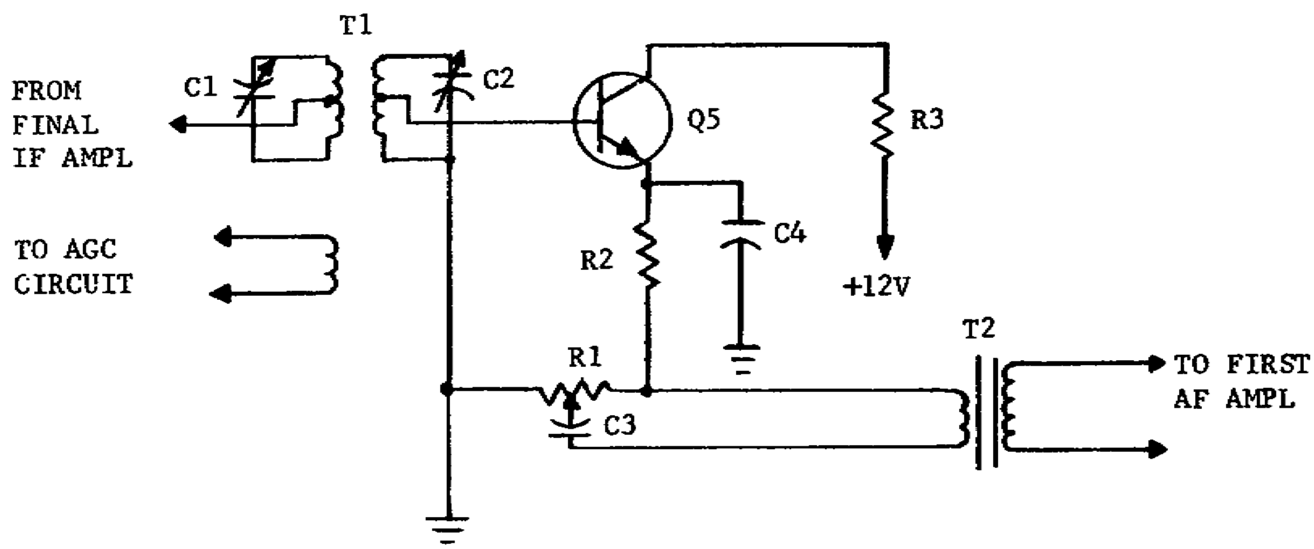

Figure 3-2. Detector.

a. IF Input Circuit. The IF signal is applied to the base-emitter junction of the transistor through transformer T1, which is physically the output transformer of the final IF amplifier stage. Since there is no forward-biasing network, the stage remains cut off until a signal is applied to it. During the positive half of the signal, a small current flows through base-emitter circuit R1 and R2. A larger collector-emitter current flows through R3, R1, and R2. During the negative half of the signal there is no current flow. The IF components of the signal are removed by filter capacitor C4, which will not pass the audio signal fluctuations.

b. IF Output Circuit. IF voltage for use in the AGC circuit is taken from a third winding (tertiary winding) on transformer T1.

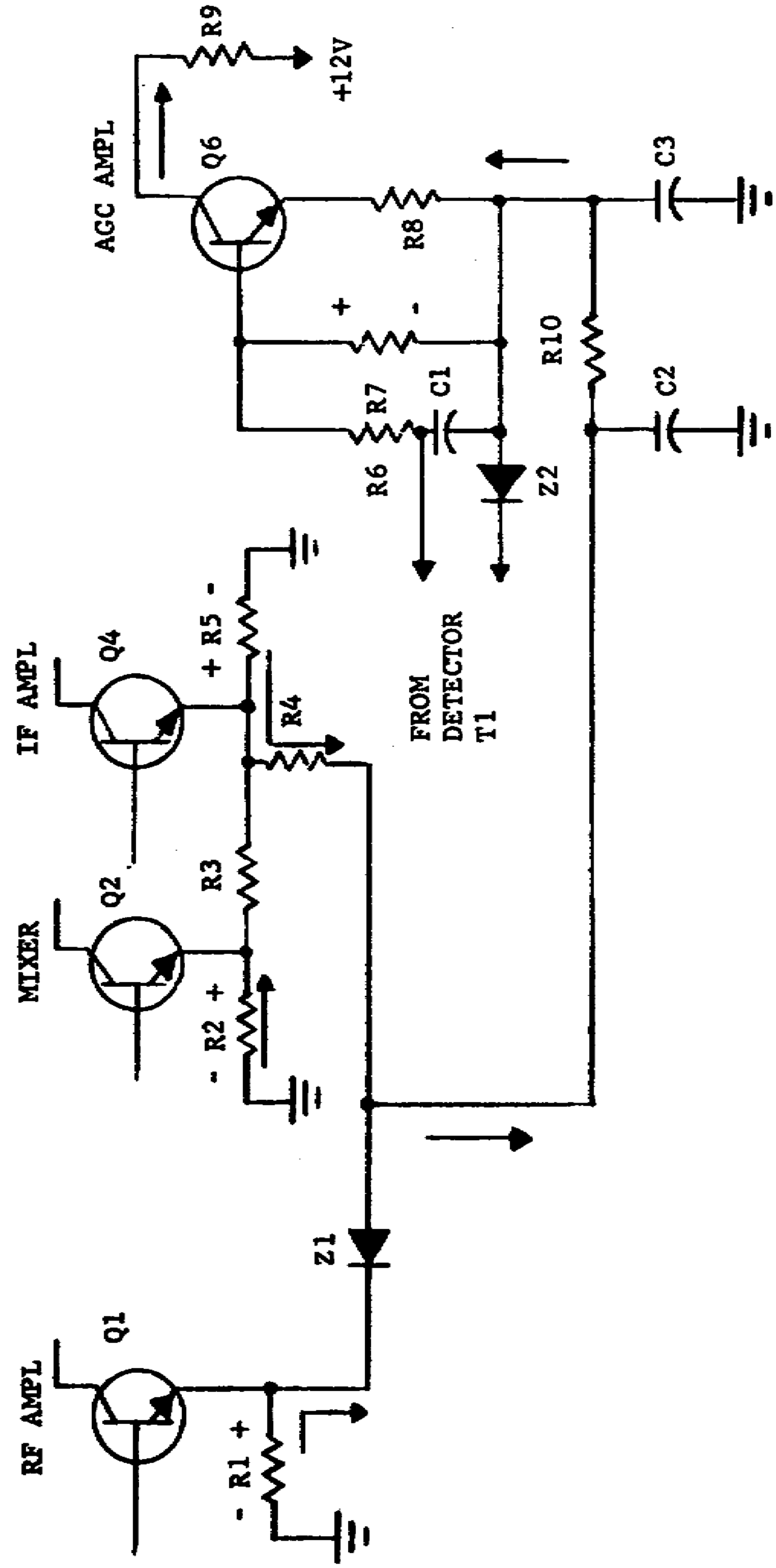

Figure 3-3. Automatic gain control.

c. AF Output Circuit. Resistors R1 and R2 form the detector load. Voltage developed across the load resistors causes current to flow in the primary circuit of AF output transformer T2. Resistor R1 serves as the volume control since its setting determines the amount of voltage applied to the primary of T2.

3-3. TRANSISTOR AGC CIRCUIT

(fig. 3-3)

a. IF Input Circuit. The same transformer (T1) that serves the detector also supplies the IF voltage necessary for operation of the AGC circuit. A third winding on T1 couples voltage into the base-emitter circuit of the AGC amplifier. The signal developed across this winding causes diode Z2 to develop the AGC voltage across R7 with the polarity indicated. Capacitor C1 serves to shunt the IF signal pulsations away from the AGC amplifier.

b. AGC Output Circuit. Resistors R2 in the mixer and R5 in the first IF amplifier emitter circuits provide ground returns for the AGC amplifier. Current flow (dc), shown by arrows, produces a voltage drop proportional to signal strength, across each of the resistors. The dc potential developed by the current flow makes the emitter of each stage more positive. In turn, the forward bias of each of these stages is reduced, driving the transistors closer to cutoff and reducing their gain. The stronger the antenna signal, the greater will be the voltage drops across the resistors (R2, and R5) and the lower the gain of these stages. The AGC circuit thereby controls the gain of the receiver.

c. AGC Delay Circuit. Resistor R1 in the RF amplifier provides a ground return for the ACC amplifier. A delay diode (Z1) delays the application of AGC voltage to the RF stage only. This RF amplifier delay keeps the amplifier operating efficiently over a wider change of signal amplitude than the mixer and IF stages. The net result is that the RF amplifier receives no AGC voltage until the signal amplitude rises to a value high enough to exceed the positive voltage on the RF amplifier side of the delay diode. This is the threshold value of signal voltage. Consequently, the AGC voltage does not control the gain of the RF amplifier signal amplitude until its output voltage equals the threshold value. However, the IF and mixer stages always receive a value of AGC voltage proportional to the IF signal strength.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. The type of detector which develops an output proportional to the amplitude of the RF input voltage is a

a. linear detector.

b. full-wave detector.

c. square-law detector.

d. weak-signal detector.

2. The infinite-impedance detector and the plate detector are used in circuits where strong signals are to be expected. Compared with the plate detector, however, the infinite-impedance detector has the advantage of

a. providing an AVC voltage.

b. providing high selectivity.

c. high signal sensitivity.

d. linear operation with both very weak and very strong input signals.

3. A bandwidth of 10 kHz is considered sufficient for IF bandpass requirements in typical AM receivers, but much narrower bandwidths are permissible in some receivers. The purpose of using bandwidths that are narrower than 10 kHz in military communications is to

a. prevent distortion.

b. furnish optimum gain.

c. provide faithful reproduction of speech and music.

d. provide a compromise between intelligibility and interference rejection.

4. A typical IF amplifier circuit is shown in figure 187 of TM 11-665. The purpose of R3 and C6 is to

a. isolate the amplifier from the power supply.

b. provide feedback to sustain oscillations.

c. filter RF frequencies from the carrier.

d. flatten IF response.

5. When three IF amplifier stages are used together in a superheterodyne receiver, stray coupling tends to cause the amplifiers to oscillate. Instability due to such oscillations can be reduced by

a. using bypass capacitors, shielding the circuits, or designing the circuits carefully.

b. shielding the circuits, designing the circuits carefully, or using remote cutoff tubes.

c. designing the circuit carefully. using remote cutoff tubes, or using bypass capacitors.

d. using remote cutoff tubes, using bypass capacitors, or shielding the circuits.

6. Assume that a radio receiver uses an IF strip consisting of three identical amplifiers in cascade (series). If the gain of each amplifier is 10, the overall gain of the IF strip is

a. 30.
b. 100.
c. 300.
d. 1,000.

7. The selection of an intermediate frequency in a receiver is a compromise between conflicting characteristics. Compared with the high intermediate frequencies, a characteristic of the lower IF's is

a. low gain.

b. poor selectivity.

c. increased image interference.

d. improved frequency stability.

8. The selectivity of a receiver should be high to override noise and overcome adjacent channel interference. The selectivity in the IF stages of a superheterodyne receiver can be increased by

a. inserting loading resistors.

b. stagger-tuning the IF stages.

c. providing a regenerative circuit.

d. using a galena crystal in a balanced bridge circuit.

9. Assume that an interfering signal is approximately 1,000 Hz from the desired signal frequency passing through the IF amplifier in A of figure 188 (TM 11-665). The interfering signal can be effectively rejected by adjusting capacitor

a. C1.
b. C2.
c. C5.
d. C6.

10. Several types of detectors are used in various AM radio receivers. The diode detector is preferred over other types of detectors in AM receivers because the

a. output waveform is a mirror image of the input waveform.

b. diode can handle high-level signals with less distortion than other types of detectors.

c. diode detector has no gain and therefore does not magnify the amplitude of distortion products.

d. curved characteristic of a diode provides the most efficient operating condition for detection.

11. In the diode detector circuit shown in figure 190 of TM 11-665, the carrier is separated from the audio signal because one circuit element offers low opposition to intermediate frequencies and high opposition to audio frequencies. The circuit element that is used for this purpose is

a. C.
b. C_O.
c. C_c.
d. R.

12. Radio reception is greatly improved by the use of the AVC circuit. This circuit is used in a communication receiver to

a. vary the output volume of the receiver automatically when the signal input changes.

b. counteract the effects of fading by keeping the output volume relatively constant.

c. change the bias of sharp cutoff tubes to control the amplification.

d. increase the sensitivity of the receiver.

13. To develop a smooth AVC voltage in a superheterodyne receiver, the modulated signal is rectified and filtered to separate the RF and AF components. The stage in which the AVC voltage is developed is the

a. detector.
b. converter.
c. RF amplifier.
d. IF amplifier.

14. One method of muting a communication receiver and eliminating reception of noise when a station is not being received, is to apply a squelch or quiet AVC bias voltage to

a. a triode or pentode tube for development of a cutoff bias for the first detector stage.

b. a control tube for creation of a blocking bias for the AF amplifier.

c. the grid of the diode detector.

d. Rf and IF stages.

15. A transistorized radio communication receiver normally uses more IF amplifiers than a comparable electron-tube receiver because the

a. transformers in the transistorized receivers are replaced by capacitive-coupled circuits.

b. transistorized IF amplifiers never use double-tuned transformers.

c. gain of a transistorized IF amplifier is less than that of an electron-tube IF amplifier.

d. impedance of a transistorized IF amplifier circuit is low and is therefore less susceptible to feedback.

16. Three methods to limit bandwidth of the IF signal are in use in various communication radio receivers. These three methods involve the use of

a. variable-coupled transformers, band-limiting filters, and crystals.

b. band-limiting filters, crystals, and adjustable coupling capacitors.

c. crystals, adjustable coupling capacitors, and variable-coupled transformers.

d. adjustable coupling capacitors, variable-coupled transformers, and band-limiting filters.

17. Assume that you are comparing the characteristics of four transistorized radio receivers with intermediate frequencies of 262, 336, 445, and 465 kHz. The receiver from which the greatest gain and stability can be obtained is the one with an IF of

a. 262 kHz.

b. 336 kHz.

c. 445 kHz.

d. 465 kHz.

18. The function of resistor R1 in figure 3-2 of the attached memorandum is to

a. vary the AGC voltage.

b. adjust the output volume.

c. control the forward bias for Q5.

d. broaden the response of transformer T2.

19. The function of diode Z2 in figure 3-3 of the attached memorandum is to

a. delay the application of AGC voltage.

b. develop the base-emitter bias for the AGC amplifier.

c. demodulate the IF to supplement the detector AF output.

d. develop the AGC voltage by rectifying a sample of the IF.

20. The purpose of the AGC delay diode in figure 3-3 of the attached memorandum is to

a. control the gain of the RF and IF amplifiers simultaneously.

b. cut off the mixer until the signal reaches a threshold value.

c. reduce the mixer gain to a different value from that of the IF amplifier.

d. prevent the RF amplifier gain from changing until the signal amplitude reaches the threshold value.

CHECK YOUR ANSWERS WITH LESSON SOLUTIONS ON PAGE 51.

LESSON 4

AUDIO CIRCUITS AND REPRODUCERS

SCOPE ....Noise discrimination; AF amplification; coupling; distortion; degeneration; reproducers; transistorized AF amplifiers.

CREDIT HOURS 1

TEXT ASSIGNMENT ....TM 11-665, para 115, 144-148, 151; Attached Memorandum, para 4-1.

MATERIALS REQUIRED ....None

SUGGESTIONS ....Read assignment in TM 11-665 before reading the attached memorandum.

LESSON OBJECTIVES

When you have completed this lesson, you will be able to:

1. Explain the operation of audio amplifiers.

2. Minimize frequency and harmonic distortion in the audio stages.

3. Explain the operation and application of the various methods of coupling between audio stages.

4. Explain how AF current variations are converted into sound waves.

5. Explain the operation of transistorized audio circuits.

ATTACHED MEMORANDUM

4-1. TRANSISTORIZED AF AMPLIFIERS

a. Preamplifiers. In transistor receivers, audio preamplifier stages are used whenever the detector output is insufficient to drive the audio output stage. Figure 4-1 illustrates such a preamplifier stage, using a medium-power PNP transistor in a class A amplifier circuit.

(1) Biasing. The emitter-base forward bias is obtained from a +12-volt source connected to the R1-R2-R3 voltage-divider network.

(2) Signal path. The detector output is transferred into the secondary of input transformer T1 which carries both the input signal and the bias voltage to the base. The C1 is a bypass capacitor to prevent

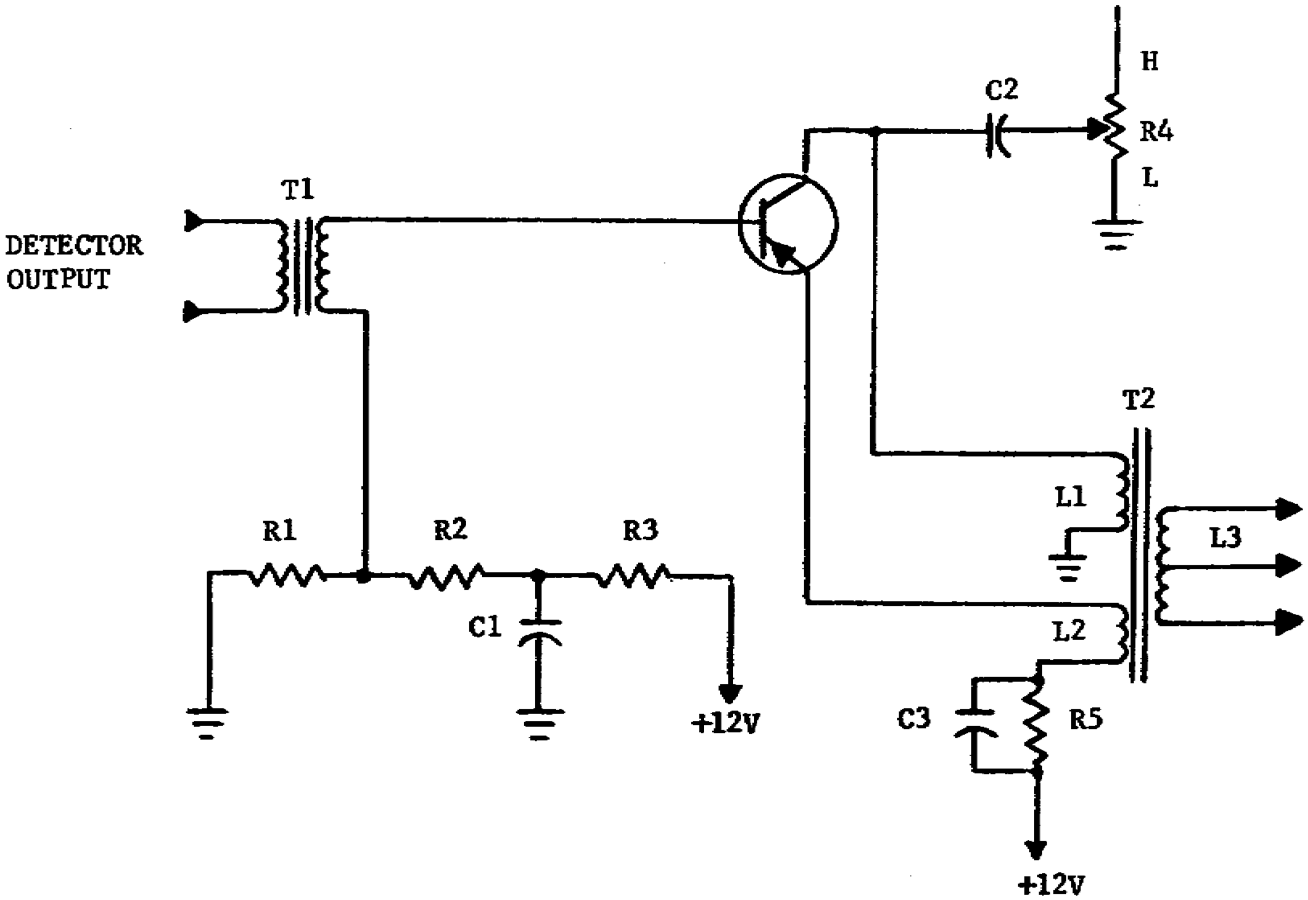

Figure 4-1. Transistor preamplifier.

a degenerative voltage from developing at this point. The 12-volt source also connects to the emitter through R5 and winding L2. The collector is connected in series with primary winding L1 of output transformer T2. With no signal input, the collector current flows at a constant value. When the input signal is applied to T1, the collector current varies at the signal rate. The output signal appearing across L1 is a replica of the input signal, but greater in amplitude. The signal voltage is induced into L3, where it is fed to the audio output stage. The same voltage is also induced into L2. The voltage across L2 is degenerative and cancels a portion of the original current appearing in the base-emitter circuit. This action is desirable because at this point in the circuit the degenerative signal minimizes distortion by canceling the harmonics which are generated within the transistor. Harmonic distortion cannot be canceled out until it occurs.

(3) Tone control. Tone control resistor R4 is connected to the collector through C2. Functionally, this control changes the amount of resistance in series with C2 and ground. The lower the resistance, the more efficient C2 becomes as a bypass for higher frequencies. With the control arm at position L, a maximum amount of high-frequency audio is bypassed and the tone quality is at its lowest. As the control is moved toward H, more resistance is added and less high-frequency audio is grounded, thus producing better tone quality.

b. Single-Ended AF Output Stage. A class A single-ended audio-output stage employing a high-power PNP transistor is shown in figure 4-2.

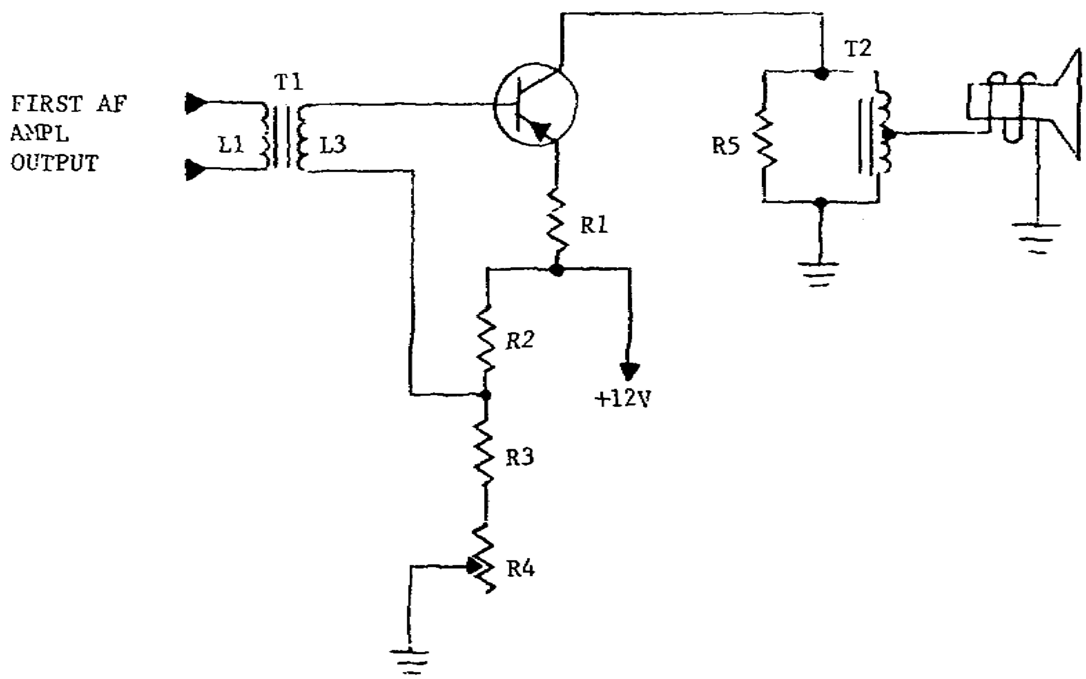

Figure 4-2. Single-ended transistor output amplifier.

(1) Biasing. A common-emitter circuit is used, where the forward bias is developed across R1 from the +12-volt supply in the R2-R3-R4 voltage-divider network. The magnitude of the bias and, consequently, the output signal level are changed by varying R4, the bias-adjust control. Although this control does affect the output volume, it is not a substitute for a volume control; a volume control is normally included as part of a detector circuit. The primary purpose of R4 is to set the operating conditions for the transistor to maintain the low-distortion output that is characteristic of a class A amplifier. This biasing circuit is a series-parallel circuit. The R4 and R3 are in series with the 12-volt supply and the circuit consisting of R2 in parallel with L3, the base-emitter junction, and R1. With R4 set at maximum resistance, 12 volts is dropped across the entire series-parallel circuit and a fixed amount of current is permitted to flow. If R4 is reduced to minimum resistance, the total resistance is reduced so that more current will flow for the same applied voltage. More current through R1 means a larger difference of potential between the base and emitter. This increase in forward bias results in an increase of collector current. Resistor R1 stabilizes the collector current, and prevents a possible runaway condition due to transistor heating.

(2) Signal path. The input signal is coupled from the audio preamplifier to the base-emitter circuit, amplified, and then coupled to the loudspeaker through autotransformer T2. Resistor R5 protects

the transistor from high surges of back voltage, which would occur if the loudspeaker voice-coil winding should become disconnected. A small power loss is accepted as the price for protecting the transistor.

c. Push-Pull Output Stage. Where more power is required than a single-ended amplifier can furnish, two transistors can be combined in a push-pull amplifier. This type of amplifier has the combined advantages of greater output and the ability to cancel out many of the distortion products created by the transistors. Figure 4-3 illustrates a class AB power amplifier employing two PNP high-power transistors in a push-pull circuit.

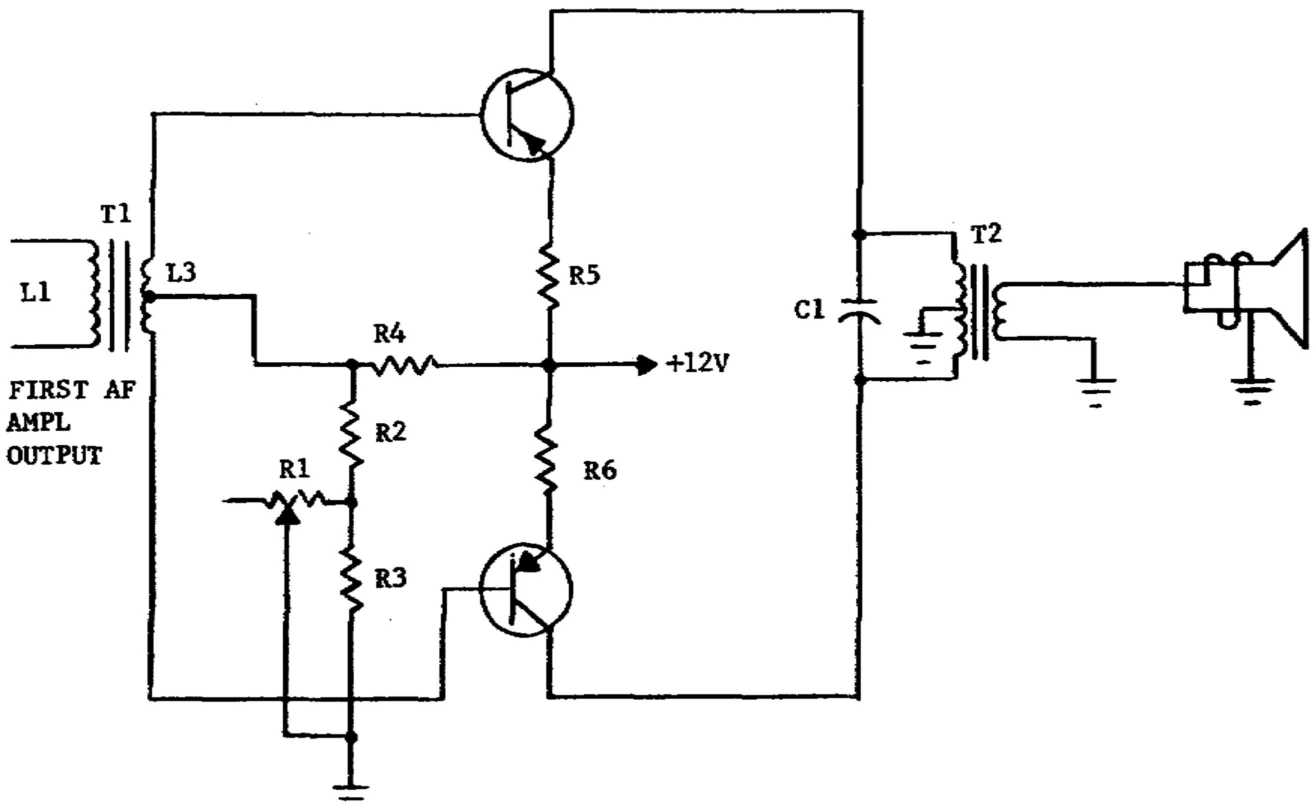

Figure 4-3. Push-pull transistor output amplifier.

(1) Biasing. A common-emitter arrangement is used with +12 volts applied to the two emitters through R5 and R6. Resistors R1 through R4 form a voltage divider to develop a bias voltage. The base of each transistor is connected to its respective emitter circuit through one half of input transformer T1 and resistor R4. Both collectors are connected to ground through one half of the T2 primary, the output coupling transformer that drives the loudspeaker. Resistor R1 provides a convenient adjustment in setting the class of operation by determining the applied bias voltage.

(2) Signal path. As the signal drives the base of one transistor positive, the other base is driven negative. On the other half of the

audio signal the reverse occurs, which is typical of push-pull circuits. Capacitor C1 improves the amplifier's frequency response and stabilizes its output. Capacitor C1 is chosen so that the combination of C1 and T2 does not resonate within the audio-frequency band to be passed by the amplifier. Negative feedback (degeneration) is not necessary because the push-pull circuit cancels most of the distortion that is created within the transistors.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. Voltage and power amplifiers are used together in high-power audio amplifiers. Tubes selected for the final stage of a high-powered audio amplifier are characterized by a high

a. amplification factor and small plate current.

b. amplification factor and large plate current.

c. transconductance and large plate current.

d. transconductance and small plate current.

2. One of the characteristics of the resistance-coupled amplifier circuit shown in B of figure 193, TM 11-665, is:

a. the value of R_g is usually smaller than that of R_L

b. a coupling network always adds to the stage gain.

c. the output voltage is reduced when R_L is made too large.

d. a frequency response falls off rapidly at frequencies above the resonant peak.

3. For coupling between AF stages, transformer coupling is usually preferred to resistance or impedance coupling because

a. transformer coupling is inexpensive.

b. the transformer can provide additional gain.

c. the amplification can easily be made uniform over the entire AF range.

d. due to self-resonance, there is little harmonic distortion in a transformer.

4. For maximum transfer of power between stages, the output impedance of the first stage must be matched to the input impedance of the second. The coupling method that best can match the high impedance of a power amplifier to the low impedance of a loudspeaker voice coil is

a. direct coupling.

c. resistance coupling.

b. impedance coupling.

d. transformer coupling.

5. Frequency distortion must be negligible in an audio amplifier if good fidelity is to be expected. This type of distortion is produced in an audio amplifier when

a. negative feedback is permitted to occur.

b. the amplification of each input frequency is not uniform.

c. the amplitudes of different signal frequencies vary in the output.

d. certain additional frequencies, not present in the original input signal, are reproduced.

6. The most important consideration in voice communication is that the receiver provides

a. high fidelity.

b. good intelligibility.

c. high harmonic content.

d. low-frequency distortion over the entire AF range.

7. The reason that harmonic distortion more seriously affects the quality of an audio signal than does frequency distortion is that harmonic distortion

a. attenuates frequencies on either side of the 150-to 3,500-Hz band.

b. minimizes the sum and difference frequencies that improve speech quality.

c. introduces new frequencies that were not originally present in the signal.

d. cancels out the intermodulation products that produce intelligible speech.

8. Degeneration, or negative feedback, improves the operating characteristics of an audio amplifier by reducing the frequency and nonlinear distortion, and by improving the amplifier's stability. The function of a negative feedback circuit is to feed back a voltage that

a. equals the output signal voltage.

b. opposes the applied input signal voltage.

c. remains constant regardless of amplifier loading.

d. increases the amplifier's gain by adding to the input voltage.

9. A large paper cone is connected to the voice coil of a dynamic loudspeaker to

a. minimize mechanical resonance.

b. cancel out harmonic distortion of the ac waveform.

c. reproduce high and low frequencies with equal efficiency.

d. efficiently radiate sound waves by pushing large amounts of air.

10. Four types of loudspeakers are shown in figures 203 and 204, TM 11-665. The loudspeaker that does NOT use a permanent magnet is shown in

a. A of figure 203.

b. B of figure 203.

c. A of figure 204.

d. B of figure 204.

11. Assume that an output transformer in a push-pull electron-tube amplifier must be replaced because of failure. This transformer has been used to match the plate-to-plate impedance of 5,000 ohms to a voice coil impedance of 8 ohms. The replacement transformer should have a turns ratio of approximately

a. 15 to 1.

b. 25 to 1.

c. 625 to 1.

d. 900 to 1.

12. In the power amplifier circuit shown in B of figure 205, TM 11-665, the plates are connected in series through the primary of the output transformer. The primary is center tapped to permit feeding equal dc plate voltages to the tubes. There must be enough turns in the primary winding so that

a. each half of the winding matches the plate-load impedance of one tube.

b. there is a direct impedance match between the primary and secondary.

c. two output signals, 180° out of phase, may be taken simultaneously.

d. two output signals of equal amplitude may be taken simultaneously.

13. In the transistor AF preamplifier shown in figure 4-1 of the attached memorandum, degenerative voltage is taken from coil L2 in the output rather than from resistor R3 in the input because

a. the voltage in L2 is in phase with the voltage in R3.

b. there is normally less dc voltage drop across L2 than across R3.

c. coil L2 couples the degenerative voltage into the following stage.

d. degeneration cannot cancel out distortion before distortion occurs.

14. The primary function of resistor R4 in figure 4-2 of the attached memorandum is to

a. vary the output volume.

b. adjust the bias voltage.

c. modify the output tone quality.

d. protect the transistor from the effect of runaway.

15. There is no provision for degenerative feedback from the output to the input circuit of figure 4-3 (attached memorandum) because the

a. transistors are free of distortion due to the balanced input.

b. harmonic distortion is prevented by proper adjustment of bias voltage.

c. flywheel effect of the tuned output circuit overcomes harmonic distortion.

d. push-pull circuit cancels out most of the harmonic distortion created by the transistors.

CHECK YOUR ANSWERS WITH LESSON SOLUTIONS ON PACE 52.

LESSON 5

RADIO RECEIVER OPERATION AND CIRCUIT ANALYSIS

SCOPE .... Power supplies, circuit analysis of electron-tube and transistorized receivers, tuning indicators, CW detection; troubleshooting AM receivers.

CREDIT HOURS 2

TEXT ASSIGNMENT .... TM 11-665, para 150, 152-153, 156-160; Attached Memorandum, para 5-1 through 5-4

MATERIALS REQUIRED .... None

SUGGESTIONS .... Read assignment in TM 11-665 before you read the attached memorandum.

LESSON OBJECTIVES

When you have completed this lesson, you will be able to:

1. Identify the various types of power supplies used in radio receivers.

2. Explain the operation of the various circuits in a radio receiver.

3. Use meters as tuning indicators in communication receivers.

4. Explain how CW detection is accomplished.

5. Troubleshoot a radio receiver using an orderly procedure.

DNI CORRECTIONS TO TM 11-665

Page 244, para 152e, last sentence. Delete "R20" and substitute C20.

ATTACHED MEMORANDUM

5-1. TRANSISTORIZED AM RADIO RECEIVERS

Transistorized radio receivers for AM radio broadcast are so practical and inexpensive that almost everyone owns one for his personal use. For this reason a description of the receivers' size and weight is hardly necessary. The schematic diagram of one type of transistorized broadcast radio receiver is shown in figure 5-1. When communication-type transistorized radio receivers become generally available, they probably will use similar schematics.

Figure 5-1. Transistorized radio receiver, schematic diagram.

(Located at the back of the lesson booklet.)

However, other circuits will have to be added to permit reception of CW telegraph signals as well as special circuits to minimize the effect of internal noise that most present-day transistors generate.

a. RF Circuit. Coils L1 and L2 along with a ferrite core serve as the antenna. The tuned circuit (L2-C2) selects the desired frequency and develops maximum voltage from the received radio waves. low-impedance winding L1 inductively couples the signal into the input of transistor Q1. Transformer T1 provides a feedback link to the transistor to overcome circuit losses and cause oscillations at a frequency determined by the tuned circuit formed by C3 and the inductance. Ganged capacitors C2 and C3 provide frequency tracking between the oscillating tank circuit and the input tuned circuit to maintain a frequency difference equal to the IF. The output frequencies developed by Q1 contain the modulated IF that is selected by the tuned circuit consisting of C5 and the primary of transformer T2. It can be seen that Q1 serves as an oscillator, a mixer, and an IF amplifier.

b. IF Circuit. The two IF stages are conventional-type amplifiers using NPN transistors Q2 and Q3. Each output circuit consists of a tuned-primary transformer having a low-impedance secondary. Transformer T3 feeds the second IF stage, while transformer T4 feeds the IF to diode rectifier Z1. This rectifier serves as both a detector and a source of AVC voltage. The AVC voltage, developed across R10, is furnished to Q2 through R9. Only the first IF amplifier in this receiver is controlled by AVC. A stable biasing voltage for Q3 is furnished by the drop across R13 in the audio stage. A portion of the output from each IF stage is fed back to the input through C7 and C11. This feedback system provides an out-of-phase voltage to prevent the IF amplifier stages from oscillating.

c. AF Circuit. The audio signal developed across volume control R10 (which also doubles as the AGC voltage source) is coupled into Q4 through C16. The output from this class A amplifier drives a miniature loudspeaker. Usually a receiver of this type is equipped with a headphone jack which cuts out the speaker when the headphone cord is plugged in. Tone controls are not normally included in receivers of this size, because the reproduction quality of miniature loudspeakers will not permit the development of all frequencies in high fidelity sound. Hence adjusting a tone control will not do much to improve sound quality.

5-2. TROUBLESHOOTING AN AM RECEIVER

When a radio receiver is brought to you for servicing, you must put the set back in normal operation. The person submitting the repair order isn't particularly interested in how you do it. Solving the problem is all up to you. Naturally, you'll want a troubleshooting method that will help you find the trouble in the least time and with the least effort. Ask yourself the following questions and see how you rate. If you don't come up to par, remember that as you gain experience you will be able to give a better answer to many of the following questions.

a. Basic, but important: do you understand AM receivers? Are you familiar with combination receiver-transmitters?

b. Do you know how to operate the receiver?

c. Do you know the stages in your receiver and the job that each stage does?

d. Can you follow a schematic diagram reasonably well?

e. Are you familiar with the test equipment you'll be using? Do you know the purpose of each piece of test equipment?

5-3. GENERAL PROCEDURE FOR TROUBLESHOOTING

Unfortunately, there is no one set step-by-step procedure for you to follow which is good for all receivers you'll work on. Too many differences exist within the receivers themselves. However, you can develop an overall method of troubleshooting which will help you get started and avoid the old "try this, try that" technique. Once you've developed a method, you'll attack each set in the same way. First of all, you should always have the technical manual (TM) for the specific piece of equipment. In addition to giving you all of the schematic diagrams you'll need, the TM provides the step-by-step procedure for troubleshooting the specific set you're working on. Refer to the section on troubleshooting. Every equipment TM has a section about troubleshooting. The whole idea of troubleshooting is to isolate the trouble to a specific defective component in the receiver. Naturally, you'll have to localize trouble to the bad stage first. Then you can find the bad component by making voltage and resistance checks within the stage.

a. Visual Inspection. There is an old saying that goes like this: "What you don't see can't hurt you." It might be true in some cases, but not in troubleshooting. What you don't see can hurt you, so the moral is: As the first step in troubleshooting, take a good look at your set.

(1) A good visual inspection helps accomplish three things.

(a) It shows you how the chassis is laid out in regard to stage and component location. Use the pictorials provided in the TM, showing the top and bottom view of the chassis. This will help you to identify most of the components and stages.

(b) It may help you locate the bad component.

(c) It helps you avoid future troubles by finding and correcting frayed wires, poor mechanical connections, and loosely mounted components.

(2) While making your visual inspection, clean the set with a fine-bristled brush. Dirt is a real troublemaker, particularly on sets that are getting rugged field use. Dirt can be a source of present trouble, and it can also be a source of future trouble.

(3) Look closely for burned or blistered resistors or for bulging electrolytic capacitors. Faulty choke coils and transformers may also be found by looking for melted wax, varnish, or sealing compound around the windings. Any sign of melted insulation of this type is usually the result of overheating caused by a shorted winding.

(4) Perhaps some of the biggest troublemakers you'll come up against will be defective cables, connectors, cordage, and sockets. Field

sets that are moved frequently will develop trouble of this kind at one time or another. To check the cording, look for opens, shorts, and faulty contacts. Wiggle the cord at the socket or plug to see if good contact is being made. You should also make sure that the correct plug is in the correct socket and that a snug fit is made. In some types of aircraft radio equipment, you may have to make your own connecting cables. Give these types of cables a good once-over when making your visual inspection.

(5) Think you've covered everything? --well, not quite. How about looking for broken tubes or sockets, badly soldered joints, tube socket pins touching each other, tuning capacitor plates touching each other, or broken slugs in IF transformer cans? Any of these troubles could cause your set to be inoperative.

b. Use Your Sense of Smell. Recently burned rubber, paint, or insulation can be easily recognized by the sharp odor which lingers in the chassis long after the set is brought in for repair. Bad selenium rectifiers, caused by overheating, smell like rotten eggs. You won't have much trouble recognizing this symptom if it appears.

NOTE: Do not make any check that requires power to be turned on, unless you've checked the key circuits for shorts. Actually, the key circuit check is a resistance check which helps locate any short circuits that might damage the power supply. This check will also prevent additional damage to the equipment when power is applied.

c. Use Your Sense of Touch. In most cases, touching the electron tubes after the set has been turned on for a couple of minutes will show if the tube filaments are heated. Your sense of touch can also be used to check for faulty resistors, transformers, and capacitors. Just turn on your set for a few minutes, then turn it off. Cautiously touch the different components and see if any are overheated. Be careful of capacitors in high-voltage circuits, however. Short them out with a small jumper wire, after you've turned off the power. If you've looked over everything that has been mentioned, you've made a good all-round inspection.

d. Checking Key Circuits for Shorts. The purpose of this check is to make sure that when you connect power to your receiver or receiver-transmitter there are no short circuits in the equipment. Actually, this test consists of resistance checks which help to locate any short circuits that might damage the power supply. This check will also prevent additional damage to the equipment when power is applied. In battery-operated equipment, resistance measurements are made from pins of the battery plug to ground. In other types of power supplies, like the vibrator-type power supply, resistance measurements are made from the power-in jack to ground. Use an electronic multimeter like the TS-505/U or its equal. Compare the readings you get with those listed in the TM. If you don't get the required reading, refer to the schematic diagram of the receiver to find out which part or parts may be at fault. Since the key circuit test often indicates trouble in the power supply, the following information will prove helpful:

(1) First of all, find out what type of power supply your set has. The power supply you'll use may be any of the following: Rectifier type, battery, dynamotor, or vibrator.

(2) These are a few checks that you can make, regardless of the type of set you're working on. Check the power supply input circuit. Make a continuity check for open or shorts in the input cables, ac line cords, or on-off switches. Don't overlook fuses, as a burned-out fuse may be the only trouble. A continuity check should also be made of the output circuit of your power supply. Remember, a continuity check is always made with the power off.

(3) Then turn on your set and see if the B plus voltage is normal. Use your voltmeter to make this check.

e. Points to Look For. Here are a few specific points to look for in the various types of power supplies:

(1) Rectifier type. Check all cables leading to or from the power supply. Then check for the following:

(a) Bad rectifier tube.

(b) Open filter choke in the power supply.

(c) Filter choke shorted or choke leads shorting to chassis.

(d) Open or shorted power transformer windings. If shorted, there is a good possibility the fuse will blow.

(e) Shorted filter capacitor. If this is the trouble, the rectifier tube will glow with a bright red color and probably burn out.

(f) A short or open in the B plus line leading to any stage using power from the power supply. If shorted, there is a good possibility the fuse will blow. If open, the voltage will be removed from the stage.

(g) Open bleeder resistor (if used as voltage divider also).

(2) Battery type. If your set is battery-operated, then noisy, weak, or unstable operation is usually caused by weak batteries. Be on guard for signs of corrosion around battery terminals. If the supply voltage is not normal, replace the batteries without checking further. If your set is not going to be used for a long period of time, remove the batteries.

(3) Vibrator type. The function of a vibrator is to change a steady dc voltage to a pulsating dc voltage. This pulsating dc voltage is then converted to a higher ac voltage by a step-up transformer. Most vibrator supplies contain a vibrator, a power transformer, a rectifier, and a filter. Complete inoperation is usually caused by a defective vibrator. If the vibrator is operating normally,

you'll hear a slight buzz. If you touch a properly operating vibrator, you'll also feel a slight vibration. One word of caution: if you replace a vibrator, always put in a new buffer capacitor. Other troubles are similar to those for any conventional ac operated power supply. They are:

(a) Bad rectifier tube.

(b) Open or shorted power transformer windings.

(c) Open filter choke.

(d) Shorted or leaky filter capacitor.

(e) A short in the B plus line leading to any stage using power from the power supply.

(f) Open bleeder resistor (if used as voltage divider also).

(4) Dynamotor type. You'll find that dynamotor-type supplies are used in practically all Army aircraft, and in many vehicular installations. Except for the values of the component parts, filter circuits used in dynamotor power supplies are similar to those in rectifier units. Always disconnect the dynamotor at the output terminals before you make any resistance measurements in the filter circuit. Then you will be able to make an accurate resistance check of the filter circuit components. Some trouble points to check when examining a dynamotor power supply follow:

(a) Low battery voltage source.

(b) Loose power cable connection, or wrong cable connections.

(c) Worn dynamotor brushes. Replace those that are less than 1/4 inch long, measuring from the commutator to the brush pressure spring. Watch the polarity mark when replacing worn brushes and watch for broken or loose brush pigtails.

(d) Dirty or worn commutator. If the dynamotor commutator is accessible, hold a piece of fine sandpaper against the commutator while the dynamotor is operating.

WARNING: Don't use this method if the dynamotor puts out a high voltage like the 1,000-volt dc output in Radio Set AN/GRC-19.

(e) Open or shorted armature windings.

(f) Defective output connections.

f. Operational Check. Now that you've made a good visual inspection and checked the key circuits for shorts, you're ready to make the operational check. This check will help you sectionalize trouble in your receiver or receiver-transmitter. All this test consists of is operating the equipment

at your test bench under as close to normal conditions as possible. In some cases, you may have to take a few measurements at key test points. This operational test is important because it frequently indicates the general location of trouble. For example, in receiver-transmitter sets, it will frequently indicate whether trouble is in the receiver or transmitter circuit. It may often indicate the defective stage.

5-4. TROUBLESHOOTING BY SIGNAL SUBSTITUTION

a. What is Signal Substitution? Signal substitution is a method of troubleshooting. Its object is to localize trouble to a specific stage of your receiver, or to the coupling between stages. All you do is to inject a signal at the output, then the input of each stage starting at the speaker, and listen for the signal from the speaker or headset. The applied signal is a substitute for the signal normally present at the test point. An audio signal is applied to all test points from the speaker through the output of the detector. A modulated intermediate frequency, equal to the IF of the receiver, is applied to all test points from the input of the detector through the output of the mixer. To check the mixer and the RF stages, select a frequency from the center of the band for which the receiver is designed. This frequency should be unmodulated. This will also enable you to check the operation of the oscillator. Another way to see whether you are getting an output is to connect an output meter (ac meter) between plate and ground of the final audio stage. If you use this method, connect a 0.1-microfarad, 600-working-volt-dc capacitor in the test lead going to the plate. This will protect the meter. By using an output meter you can accurately check the value of the output signal going to the speaker or headset.

b. Use of Equipment Manual in Signal Substitution. In the troubleshooting section of the equipment manual you will find a list of the tools and equipment you will need for signal substitution. You will also find information such as the following to help you along:

(1) How to set the receiver controls before starting.

(2) At what frequency to set the signal generator for each stage you are going to check.

(3) What value of input signal you are going to inject.

(4) Test points to be used.

(5) What signal or meter indication you should get if operation is normal.

(6) What components are possibly faulty if the signal does not pass through the stage.

c. Signal Substitution Procedure. Let's take a typical AM receiver and see how to use the signal substitution method for locating a trouble. All you have to do is substitute the signal, following the order and at the points shown in figure 5-2. Remember, signal substitution is used to localize trouble to a stage. Once you have located the stage, you must test the tube in the stage and take voltage and resistance measurements to isolate the trouble to a component.

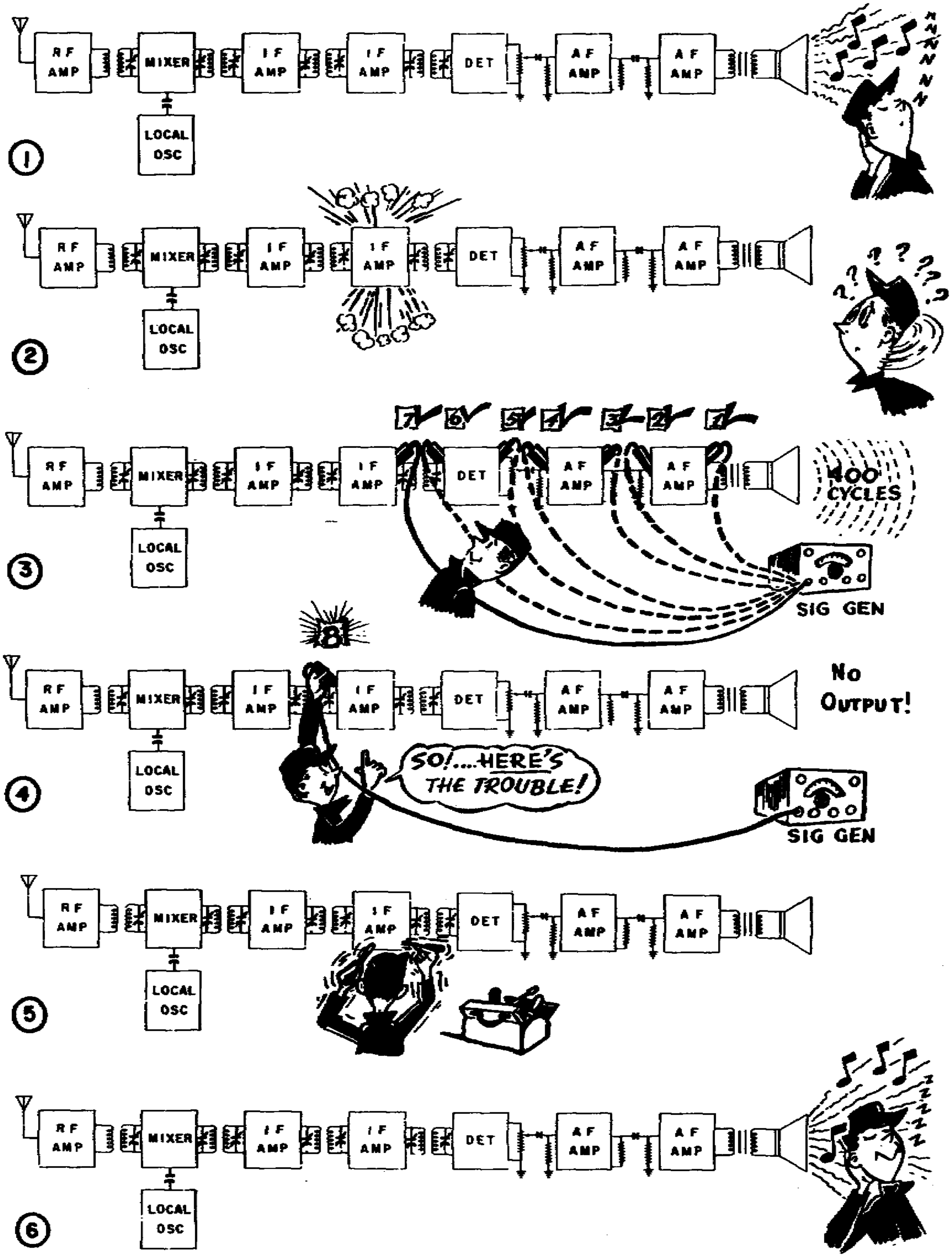

Figure 5-2. Localizing trouble by signal substitution.

d. Summary. You have covered a complete procedure to follow when troubleshooting an AM receiver. As you gain experience, you'll find that you may modify your procedure using shortcuts that will help you save time. The method by which you attack a problem involving troubleshooting should always be the same. Now, let's review what you should do. Remember to make maximum use of the equipment manual.

(1) Get an equipment manual for the specific receiver on which you are working. Examine the schematic diagram closely.

(2) Make a complete visual inspection.

(3) Check key circuits for shorts.

(4) Make a complete operational test.

(5) Use the troubleshooting procedure outlined in the TM.

(6) Use the signal substitution method whenever applicable, to help you to localize trouble in the receiver section.

(7) Check and replace the defective component.

(8) Then make a final test to be certain the receiver is once again in good operating condition. The final testing procedure is also in the equipment manual.

LESSON EXERCISES

In each of the following exercises, select the ONE answer that BEST completes the statement or answers the question. Indicate your solution by circling the letter opposite the correct answer in the subcourse booklet.

1. What circuits can be eliminated from radio receivers that operate from a battery power supply?

a. AVC and power amplifier circuits

b. MVC and power amplifier circuits

c. Rectifier and filter circuits

d. Voltage amplifier circuits

2. Selenium rectifiers are often used instead of electron tubes in rectifier circuits because a selenium rectifier

a. can rectify both halves of the input signal.

b. does not require a filter circuit.

c. requires no heater voltage.

d. requires no load resistor.

3. Which component of an ac power supply provides a constant minimum load for the power supply?

a. Rectifier

b. Input choke

c. Bleeder resistor

d. Filter capacitor

SITUATION

Exercises 4 thru 10 are based on the receiver circuit shown in figure 206, TM 11-665.

4. Three stages in this receiver use ganged tuning so as to achieve tracking. These three stages are the

a. mixer, local oscillator, and IF amplifier.

b. RF amplifier, mixer, and local oscillator.

c. local oscillator, IF amplifier, and RF amplifier.

d. RF amplifier, mixer, and beat-frequency oscillator.

5. Variations in circuit constants of the local oscillator require that minor adjustments be made to assure high-frequency and low-frequency tracking. Adjustment of high-frequency tracking of the local oscillator is made using capacitor

a. C2.

b. C3.

c. C24.

d. C26.

6. Assume that you have tuned the receiver to a broadcast station transmitting on 1,410 kHz, and that the IF is 455 kHz. What is the frequency of the local oscillator?

a. 910 kHz

b. 955 kHz

c. 1,410 kHz

d. 1,865 kHz

7. The AVC voltage is developed across resistor

a. R1.

b. R5.

c. R10.

d. R14.

8. The function of potentiometer R18 is to

a. vary the tone quality.

b. control the output volume.

c. adjust the bias on tube V4.

d. establish the AVC delay threshold.

9. The reason that transformer T5 is center-tapped is

a. so the signal applied to the grids of V5 and V6 will be in phase.

b. so the signal applied to the grids of V5 and V6 will be 180° out of phase.

c. to provide cross-neutralization and prevent oscillation in the power amplifier.

d. to provide feedback from the plates of V5 and V6 to the grids to sustain oscillation.

10. A repairman who is working on the receiver that is represented by the schematic in figure 206 should be able to identify the bleeder resistor as resistor

a. R14.

b. R16.

c. R19.

d. R24.

11. It is virtually impossible to tune a receiver entirely by ear because the AVC circuit tends to maintain a constant output from the speaker. However, a dc meter connected in series with the plate of the AVC controlled circuit (IF or RF, or both) can serve as a tuning indicator. When the receiver is properly tuned, the meter will indicate

a. maximum plate current.

b. minimum plate current.

c. maximum plate voltage.

d. minimum plate voltage.

12. The detector used in an AM radio receiver cannot be used to receive CW signals because the

a. average value of the rectified signal current is zero.

b. direct current resulting from rectification of a CW wave does not produce an audible tone.

c. audio component is lost as the signal passes through the extremely narrow bandpass tuned circuits.

d. rectified negative signal peaks cause the direct current to flow in the direction opposite to normal.

13. Most communication receivers are capable of receiving CW signals as well as voice and tone signals. To be able to receive CW signals, the receiver shown in figure 206, TM 11-665, will require the addition of a

a. crystal-filter circuit inserted in the IF stage.

b. beat-frequency oscillator to mix with the IF signal.

c. grid-leak type of detector in place of the diode detector.

d. high-frequency heterodyne oscillator to mix with the RF carrier.

14. When receiving CW signals, the operator must switch off the AVC circuit so as to prevent

a. zero beat.

b. receiver detuning.

c. changes in the audio pitch.

d. reductions in receiver sensitivity.

15. Assume that the receiver shown in figure 206, TM 11-665, has no output from the speaker. Using signal substitution, you have localized the trouble to the first AF amplifier stage. Voltage measurements show that the voltage applied to the plate of V4 is zero. A possible cause of this trouble is

a. an open C30.

b. a shorted L2.

c. a shorted R21.

d. an open T5 primary.

16. The receiver shown schematically in figure 5-1 (attached memorandum) contains an AVC circuit. The voltage that is used to compensate for changes in signal strength is developed across

a. capacitor C15.

b. resistor R13.

c. resistor R10.

d. resistor R9

17. Assume that you are about to troubleshoot an inoperative radio receiver. The first step to locate the trouble, and possibly avoid many future troubles, is to perform

a. an analysis of key circuits.

b. an operational check.

c. a visual inspection.

d. signal substitution.

18. Assume that you are troubleshooting a radio receiver and you discover a blown fuse. This could have been caused by

a. an open bleeder resistor.

b. a shorted diode detector.

c. an open audio output transformer.

d. a shorted power transformer winding.

19. Assume that you are using signal substitution to localize a trouble in the receiver shown in figure 5-2 of the attached memorandum. The trouble is in the RF stage. Before you can locate the defective stage, you will have to set the frequency of the signal generator at least

a. 2 times.

b. 3 times.

c. 4 times.

d. 5 times.

20. Assume that you are trying to locate the defect in an AM receiver and you are following the general troubleshooting procedure outlined in the attached memorandum. You will use the voltage and resistance checks when you are

a. checking the key circuits.

b. making the operational check.

c. localizing the trouble to a stage.

d. isolating the trouble to a component.

CHECK YOUR ANSWERS WITH LESSON SOLUTIONS ON PACES 53 and 54.

HOLD ALL TEXTS AND MATERIALS FOR USE WITH EXAMINATION.

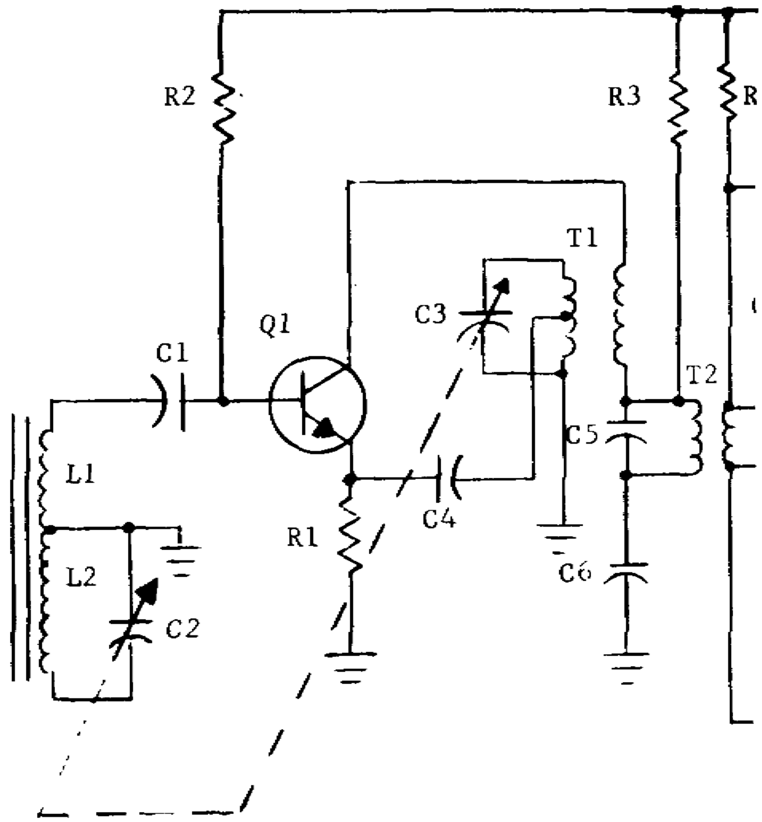

Figure 5-1. Transistorized radio receiver, schematic diagram.

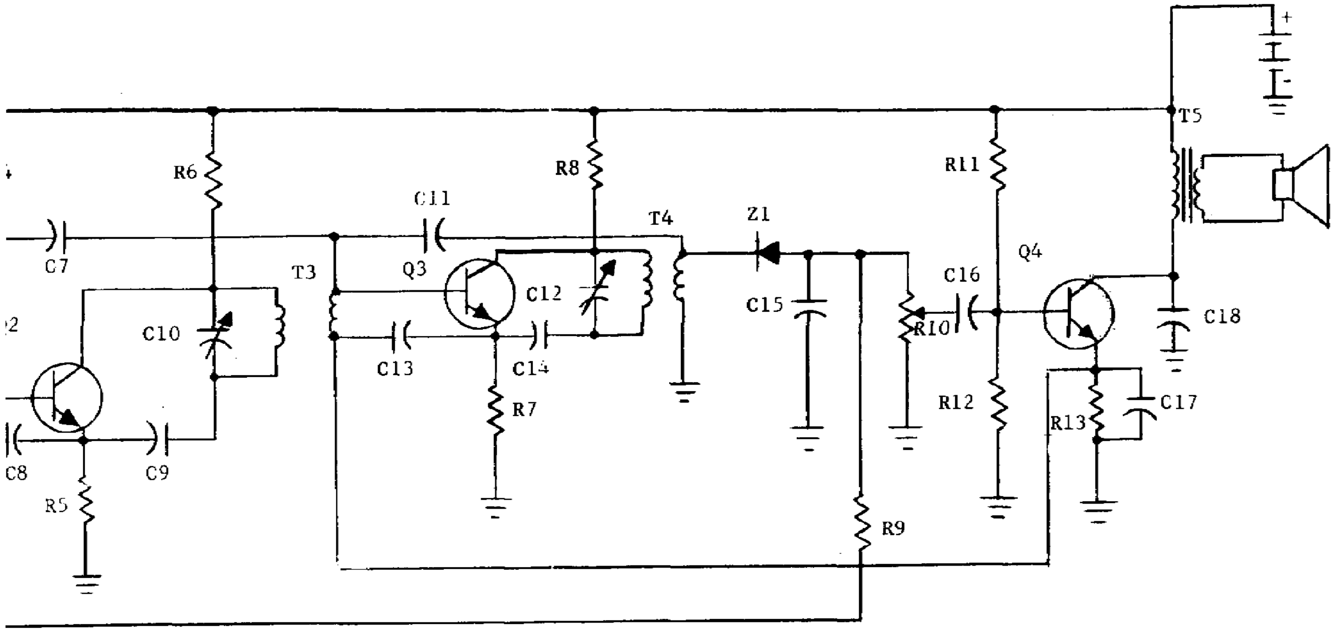

Figure 5-1. Transistorized radio receiver, schematic diagram. CONT

LESSON SOLUTIONS

SIGNAL SUBCOURSE 322......................AM Radio Receivers

LESSON 1.................................Radio Receiver Characteristics

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to TM 11-665.

1. a--para 122a
2. d--para 123e

   7,130 kHz - 7,100 kHz - 30 kHz
3. c--para 123g
4. b--para 124a
5. a--para 125b
6. a--para 126b(4)
7. d--para 102b as changed
8. d--para 106b, 125
9. c--para 106c(1)
10. c--para 106d
11. c--para 106e(2)
12. b--para 106e(3)
13. d--para 106e(9)
14. b--para 106e(9)
15. a--para 106f

All concerned will be careful that neither this solution nor information concerning it comes into the possession of students or prospective students who have not completed the work to which it pertains.

LESSON 2................................Signal Input Circuits

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to TM 11-665, unless otherwise indicated.

1. b--para 107b

2. c--para 110c

3. d--para 112

4. c--para 127a(1)

5. b--para 127b(1)

6. d--para 128c

7. b--para 128f

8. c--para 129b, c, fig. 176, 177

9. c--para 131b

10. c--para 132a

11. d--para 133b, c

12. d--para 149a(3), 149d(1)

The wavetrap should be tuned to the unwanted (image) frequency. Since the oscillator is tuned above the input signal, the image frequency is equal to the signal frequency plus twice the IF or 15.252 + (2 x 462) = 16,176 kHz.

13. a--para 149e(2)

14. c--para 149a(4)

15. c--Attached Memorandum, para 2-1

16. d--Attached Memorandum, para 2-2a

17. c--Attached Memorandum, para 2-3e

18. a--Attached Memorandum, para 2-3c, d

19. a--Attached Memorandum, para 2-4a

20. a--Attached Memorandum, para 2-4b

LESSON 3 ....IF Amplifier and Detector Circuits

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to TM 11-665, unless otherwise indicated.

1. a--para 113
2. b--para 113c(4)
3. d--para 135c
4. a--para 137b
5. a--para 137c
6. d--para 139c

The overall gain of the three identical amplifiers in the IF strip is the cube of the gain of one. $10^3 = 10 \times 10 \times 10 - 1,000$.

7. c--para 140a
8. c--para 141a
9. b--para 141b(4)
10. b--para 142a(1)
11. a--para 142b(5)
12. b--para 143a
13. a--para 143b(2), fig. 191
14. b--para 143d(3)
15. c--Attached Memorandum, para 3-1
16. a--Attached Memorandum, para 3-1a(3)
17. a--Attached Memorandum, para 3-1c
18. b--Attached Memorandum, para 3-2c
19. d--Attached Memorandum, para 3-3a
20. d--Attached Memorandum, para 3-3c

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to TM 11-665, unless otherwise indicated.

1. c--para 145b(1)

2. c--para 146b(2)

3. b--para 146a(2)

4. d--para 146d

5. b--para 147a

6. b--para 147a

7. c--para 147b

8. b--para 148a

9. d--para 151c(1)

10. c--para 151e(2)

11. b--para 151g(3), (4)

The turns ratio is equal to the square root of the impedance ratio:

$$N_p/N_s = \sqrt{Z_p/Z_s}$$

$$= \sqrt{5{,}000/8} = \sqrt{625/1} = 25/1, \text{ or } 25 \text{ to } 1$$

The primary winding must have 25 times as many turns as the secondary to match the primary impedance of 5,000 ohms to the secondary impedance of 8 ohms.

12. a--para 151g(3)

13. d--Attached Memorandum, para 4-1a(2)

14. b--Attached Memorandum, para 4-1b(1)

15. d--Attached Memorandum, para 4-1c

LESSON 5 ....Radio Receiver Operation and Circuit Analysis

All exercises of this lesson are of equal weight. The total weight is 100.

All references are to TM 11-665, unless otherwise indicated.

1. c--para 150b
2. c--para 150e(4)
3. c--para 150f(4)
4. b--para 152a
5. c--para 152b
6. d--para 152b
7. d--para 152e
8. b--para 152e
9. b--para 152f
10. d--para 152g
11. b--para 153a
12. b--para 156b
13. b--para 157d
14. d--para 160c
15. d--para 152f; fig. 206; Attached Memorandum, para 5-3e(1)(f)

    a. An open C30 causes a voltage increase and a ripple to appear.

    b. A shorted L2 causes a slight voltage increase and a ripple to appear.

    c. A shorted R21 causes a voltage increase.

    d. An open T5 primary removes plate voltage from V4.

16. c--Attached Memorandum, para 5-1b
17. c--Attached Memorandum, para 5-3a(1)(c)
18. d--Attached Memorandum, para 5-3e(1)(d)

19. b--Attached Memorandum, para 5-4a, fig. 5-2

Sketch 3 in figure 5-2 shows a signal generator being used for signal substitution. For checkpoints 1 through 5, the signal generator is set for an audio frequency (400 Hz). As the output of the generator is applied to each checkpoint, if the circuits are good a tone is heard in the speaker. When checkpoint 5 produces a tone, you know that the audio stages are good. Now the generator must be set to produce a modulated IF (455 kHz). This signal is applied to the checkpoints starting at number 7 and working toward the mixer. If the trouble is in the RF stage, you will hear a tone from all checkpoints through the output of the mixer. Now set the generator for an unmodulated RF (1,000 kHz) and apply the signal to the RF input of the mixer. If a tone is heard you know that the oscillator is good. Your trouble must be located between the antenna and the RF input of the mixer. You have set the signal generator to three different frequencies.

20. d--Attached Memorandum, para 5-3, 5-4c